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Statistical Support Document for Asbestos in Buildings Simplified Sampling Scheme for Friable Surfacing Materials

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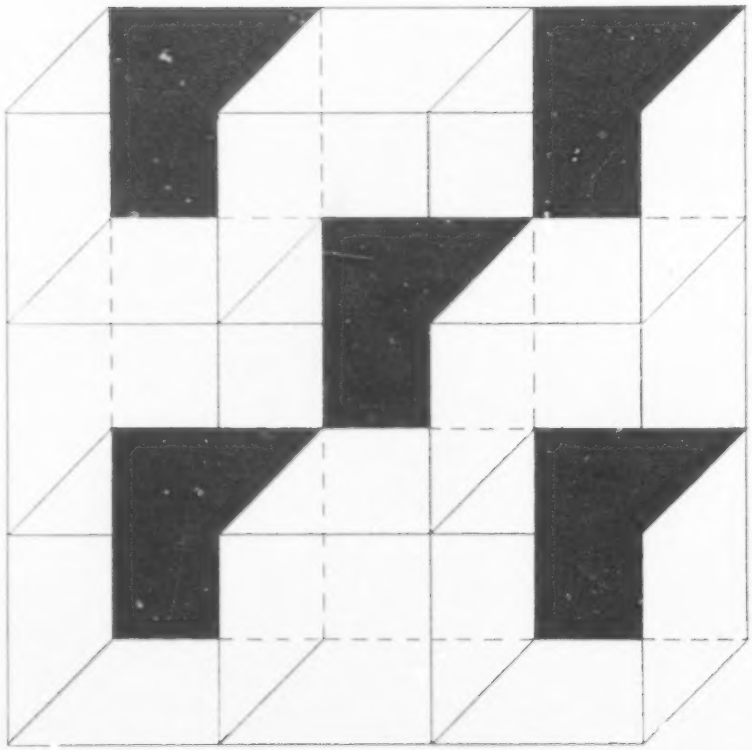

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1. INTRODUCTION

This report provides the statistical basis for the recommended sampling protocol found in "Asbestos in Buildings: Simplified Sampling Scheme for Friable Surfacing Materials" (USEPA, 1985; referred to as the primary document). Obtaining samples of friable surfacing materials is one of the first steps in testing a building for the presence of asbestos. Sampling of sprayed- or troweled-on surfacing materials, followed by analysis by Polarized Light Microscopy (PLM) to determine if asbestos is present, is required for schools by "Friable Asbestos-Containing Materials in Schools; Identification and Notification Rule" (40 CFR Part 763). Sampling and analysis programs are also conducted in other buildings to provide information for the development of risk management programs and the planning of abatement projects where necessary.

The sampling protocol, which encompasses the overall plan for sampling and analysis, must assure that the data obtained are representative of the actual situation and that sufficient information is collected to determine whether or not asbestos is present. The data will be representative if all areas that could contain asbestos have been identified and if the samples are obtained from these areas in an unbiased manner. The sampling protocol must specify the following:

- boundaries of homogeneous sampling areas (i.e., areas containing surfacing materials that are uniform in texture and appearance, were installed at one time, and are unlikely to consist of more than one type or formulation of mix);
- sampling locations within each homogeneous area; and
- the minimum number of samples required for each homogeneous area.

The boundaries of homogeneous sampling areas are determined through two activities: (1) by reviewing building documents, including construction plans and repair and renovation records; and (2) by a thorough visual inspection to find material not mentioned in records and to note changes in the appearance of materials. The sampling locations are centers of rectangles* dividing homogeneous areas into nine equally-sized subareas (see Section 6 of the primary document). A minimum of nine samples is recommended, except when the homogeneous sampling area is very small (e.g., a closet). Previous guidance recommended either three, five or seven samples for areas less than 1000

*Other shapes may be used to divide an irregular homogeneous area into equally-sized subareas.

square feet, between 1000 and 5000 square feet, and greater than 5000 square feet, respectively. In many situations these smaller numbers of samples will suffice. However, a larger number of samples provides a greater amount of information, reducing the likelihood of error. In each instance the building owner should assess the tradeoff between potential errors in determining if asbestos is present and costs associated with additional sampling and analysis.

The remainder of this report discusses each of the three requirements listed above and their recommended solutions. Information is provided that may be used to evaluate sampling schemes that go beyond those formulated here.

2. DEFINING HOMOGENEOUS SAMPLING AREAS

Locating all surfacing materials that may contain asbestos and establishing boundaries for homogeneous sampling areas are the most crucial steps in the assessment process. Errors of omission at this stage of the process dominate all other types of potential errors. If an area with sprayed- or troweled-on material is overlooked in the initial inspection, it is a potential source of asbestos that will never be tested. Detailed guidance for conducting a thorough review of records and inspection of materials is found in the primary sampling document. All subsequent discussion of statistical methods and error rates has meaning only if the definition of homogeneous sampling areas is complete.

3. LOCATING SAMPLING POSITIONS WITHIN HOMOGENEOUS AREAS

The sampling locations selected within a homogeneous sampling area should be representative of the whole homogeneous area. If the sampling area were truly homogeneous (i.e., if the asbestos were distributed evenly throughout), samples could be taken from arbitrary locations in the area. However, as a practical matter, the property of homogeneity is difficult to establish. Asbestos is mixed with filler materials, usually at the site, prior to application. It is reasonable to expect some unevenness in the distribution of asbestos in the surfacing material. Therefore, efforts to be sure that the sampled material is representative are justified.

The sampling rules proposed must satisfy three criteria. They must:

- produce representative data;
- be defensible to all interested parties (e.g., workers and other building occupants); and
- be practical to implement.

The first two criteria are inter-related and therefore must be considered together when designing a sampling strategy. Homogeneity of the area to be sampled is a critical characteristic if the sample is to be representative. Stating that an area is homogeneous assumes that all information that could be used to distinguish one homogeneous area from another has been exhausted. Any remaining deviation from uniformity in the distribution of asbestos across the area (e.g., clustering of fibers) is random. Then, a sample from one location in the homogeneous area is as informative as a sample from any other location. However, uniformity, or the lack thereof, is not a visible characteristic. To overcome concerns about the actual distribution of asbestos in the homogeneous sampling area and to further reinforce the representativeness concept, each area is divided into subareas and samples are selected within each subarea.

Sampling from different subareas assures that the samples will be spread across the homogeneous sampling area providing a greater degree of representativeness.

The selection of locations within subareas remains. The designated sampling locations within a subarea should produce a randomly selected sample of the surfacing material. The sampling procedure needs to be objective, assuring that the sample has not been selected for convenience or to serve a special purpose, and repeatable. In addition, it needs to be easy to implement (i.e., the selection can be made in the field quickly, requiring little if any information beyond what is already available). Since asbestos fibers, if present, are distributed randomly within a subarea, any sampling location identified before inspecting the subarea produces a randomly selected sample of the material. Therefore the recommended solution, which satisfies the criteria discussed above is:

Step 1. Divide the homogeneous sampling area into subareas of equal size.

Step 2. Sample from the center of each subarea.

(Guidance for constructing the subareas and locating the "center" is found in the primary document, "Asbestos in Buildings: Simplified Sampling Scheme for Friable Surfacing Materials.")

4. DETERMINING THE NUMBER OF SAMPLES FOR A HOMOGENEOUS SAMPLING AREA

Technically, if asbestos is found in one or more samples then the sampling area is classified as containing asbestos and no additional sampling is needed. Note, however, that the May 27, 1982 EPA "Friable Asbestos-Containing Materials in Schools; Identification and Notifica-

tion Rule" (40 CFR Part 763) currently requires the collection and analysis of three samples from each "distinct type of friable materials" found within a school building. It is also acceptable to assume that the sampling area contains asbestos and dispense with the sampling and analysis altogether. If this is done, the area must be treated as an asbestos-containing area. The number of samples derived here (3, 5, 7 or 9) is the number required under various situations to support a claim that the sampling area does not contain asbestos.

The number of samples required for a homogeneous sampling area is related to the probability that the test for asbestos gives the correct answer. The test determining whether or not asbestos is present is based on the sampling scheme described above and a Polarized Light Microscopic (PLM) search for asbestos fibers in the samples obtained. Since statistical variability enters both the sampling and analysis steps, the test result is subject to two sources of error:

(1) If asbestos is not distributed uniformly throughout the material, one or more samples could miss asbestos even if it is present.

(2) The laboratory performing the analysis could make an incorrect determination.

The quantitation method employed with PLM has a very low error rate in terms of detecting the presence or absence of asbestos. (Estimates of percent asbestos can vary but that is not an issue here.) Based on data collected in EPA's bulk asbestos sample quality assurance program, the probability of correctly detecting the presence of asbestos in a sample is at least 0.975 (RTI 1985). Given that surfacing material in a homogeneous sampling area consists of at least 1% asbestos, the likelihood that a sample taken from the sampling area contains asbestos has not been empirically characterized, but is believed to be typically less than 0.975. The number of samples required is determined by specifying the minimum acceptable probability of correctly identifying asbestos, considering the uncertainty in both the sampling and the analysis steps. As indicated above, the probability of finding asbestos when it is present is the product of two component probabilities: the probability that asbestos is in the sample selected when the homogeneous sampling area surfacing material contains at least 1% asbestos, and the probability of correctly determining that asbestos is present with PLM. The former probability depends on the uniformity of asbestos in the surfacing material. If asbestos is uniformly distributed throughout the material (i.e., minimal clustering of asbestos fibers), the probability that asbestos is in a sample selected at random will be large. On the other hand, if asbestos, although at least 1% by weight, was unevenly mixed or applied, the probability that it is in a randomly selected sample will be small.

The composite probability, P, of finding asbestos when it is present is

$$P = Q \times \text{Prob (correctly identifying asbestos with PLM)}, \quad (1)$$

where Q is a measure of patchiness. Q is the probability that asbestos is in the sample when the surfacing material in the homogeneous sampling area contains at least 1% asbestos. Q equal to 1 means that the material is so uniform that virtually every sample taken from the sampling area will contain asbestos. Lower values of Q indicate a patchy distribution of asbestos. If Q is small it is easy to miss asbestos by sampling, by chance, from a location that does not contain asbestos.

Although there is no empirical information about the degree of asbestos clustering or patchiness in surfacing materials, it is reasonable to expect smaller homogeneous sampling areas to be less patchy than larger areas. For example, in areas less than 1000 square feet, the probability of asbestos in an individual sample when the surfacing material in the homogeneous area contains at least 1% asbestos may be greater than 0.8. For larger areas, such as 1000 to 5000 square feet, the probability may be as low as 0.4, and for areas greater than 5000 square feet, the probability may be as low as 0.3. Since none of these probabilities are known, their values must be assumed for planning purposes.

Assuming that individual samples are statistically independent (there is no basis for assuming otherwise), the probability that at least one of n samples will show asbestos is

$$P_n = 1 - (1-P)^n. \quad (2)$$

Setting the right hand side of equation (2) equal to the desired probability level of finding asbestos and solving for n gives the number of samples required.

Figure 1 displays the probability of finding asbestos when it is present as a function of Q. This relationship is shown for values of n equal to 3, 5, 7, and 9. The values 3, 5, and 7 were chosen because they are the sample sizes recommended in previous EPA guidance (USEPA 1980a,b). A sample size of nine corresponds to current guidance which recommends dividing a homogeneous sampling area into nine equal subareas and taking at least one sample from the center of each. Nine samples are recommended because they provide a high probability of detecting asbestos for a broad range of values of Q.

Considering a probability of at least 0.95 satisfactory for detecting asbestos when it is present, Figure 1 shows that three samples ($n = 3$) are adequate only if the asbestos is extremely uniform in the surfacing material (i.e., a value of Q greater than 0.6). Using five samples ($n = 5$), allows Q to be as low as 0.45, and for seven samples ($n = 7$), Q could be as low as 0.35. When nine samples are used, as currently

recommended, the uniformity of asbestos in the surfacing material as reflected by Q could be slightly lower than 0.3. It is worth noting that the value of P is not substantially increased when the probability of correctly identifying asbestos by PLM is increased to 0.99, 0.999 or 0.9999. The choice of 0.975 used in the figure is conservative (i.e., the probability of correctly detecting the presence of asbestos in a sample is at least 0.975).

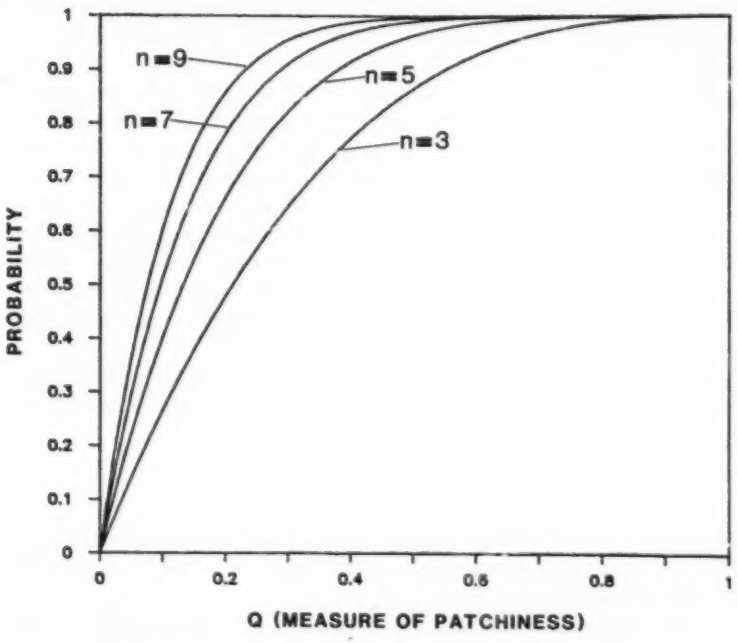

Figure 1. Probability of finding asbestos when it is present as a function of Q (where Q is the probability that asbestos is in the sample when the surfacing material in the homogenous sampling area contains at least (1% asbestos) for sample sizes of 3, 5, 7, and 9.

5. CONCLUSIONS

In a given situation, the uniformity of asbestos across the sampling area is unknown. The basic question—how many samples—can be answered only by considering various alternatives and balancing costs against the risks of erring. Increasing the number of samples always reduces the likelihood of error, but the cost of additional sampling and analysis must be considered. Additional samples have a small effect on the error rate once it is less than 0.05 (i.e., when the probability of finding asbestos when it is present is greater than 0.95).

Considering the curves shown in Figure 1, a cautious person would choose at least nine samples per homogeneous sampling area. Taking nine samples provides a 0.95 probability of finding asbestos when it is present for most reasonable assumptions about the uniformity of asbestos in the sampling area. Since the combined process of sampling and PLM analysis is relatively inexpensive, the recommended number of samples is nine. Previous guidance indicated three, five or seven samples depending on the number of square feet in the homogeneous sampling area. Certainly for very small areas, fewer than nine samples may be sufficient. Three, five or seven samples can be justified by ascertaining the degree of uniformity.

If fewer than nine samples are used, the sampling locations should be selected in an unbiased and objective manner. The primary document provides a scheme, based on random numbers, for selecting samples from a subset of the nine subareas. Following this scheme removes the potential for criticism when no asbestos is found; that is, the samples were selected for the convenience of the building owner. In general, once all systematic factors have been used to define homogeneous sampling areas and subareas, selection by a random number scheme should follow. Such schemes are objective because a third party not involved in the design can follow the documentation that has been prepared and arrive at the same selections.

Finally, none of the sample size recommendations or probability computations are meaningful if the search for surfacing materials that could contain asbestos has been inadequate. Surfacing materials containing asbestos that go undetected will never be sampled. Also, all available information must be used to define homogeneous sampling areas. If an area defined as homogeneous is known to consist of two or more material formulations, the sampling scheme proposed has a much greater chance of erring than planned. There are no statistical principles to guide the search. However, if the search is not complete, or the definition of homogeneous sampling areas is applied haphazardly, the recommended sampling approach will not achieve the intended objective.

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